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VEHICULAR INTERCOMMUNICATIONS SYSTEMS

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This is the Final Report for the brassboard phase of the VIS program. The report presents results of a brassboard system test on a M-60 tank and M-577 APC. The results show feasibility of a digital voice, time division multiplexed, pulsed IR intercom system on board combat vehicles.

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1. INTRODUCTION

This report documents the test results of the brassboard Intercom System developed under Contract DAAB07-77-C-0189. The brassboard was developed to provide feasibility testing of techniques recommended as a result of the initial phase of Contract DAAB07-77-C-0189.

The brassboard intercom test phase was a 7-month program, resulting in a brassboard intercom system utilizing techniques recommended in the study. The brassboard system was built to be tested in an M-60 tank and an Armored Personnel Carrier (APC). The testing was conducted at Fort Knox, Kentucky during the week of October 15, 1979.

The techniques recommended by ITT Aerospace/Optical Division (ITT-A/OD) were:

1. TDM signaling between crew stations utilizing continuously variable slope delta (CVSD) modulation devices

2. Infrared radiation for application as a wireless intercom

The testing was qualitative in nature with voice clarity and background noise levels being the areas of most interest. The brassboard system performed with very little background noise even with the vehicles operating at high rates of speed (high noise environment) and provided good intelligible communications. The test proved the feasibility of using one or both techniques in tracked vehicles. The information derived from this testing will provide information which will help formulate future intercom systems.

2. BRASSBOARD SYSTEM DESCRIPTION

The test system was developed to prove feasibility of techniques recommended by the first phase of the Vehicular Intercommunications System Study. The system can best be described by dividing the test system into a primary system and one subsystem. The primary

system is the wireline system. The subsystem will be the wireless portion of the intercom utilizing infrared radiation. The block diagram of the total system is shown in Figure 1. The brassboard test system was developed to establish feasibility of technique and therefore some functions normally common to the intercom which did not utilize new techniques were not included in the brassboard system. These functions were multiple radio interface and external station control. The system interfaced with one radio. The wireline system consisted of a commander's station and three crew stations. The techniques utilized in the primary wireline system which are of interest were the Continuously Variable Slope Delta (CVSD) modulation devices operating at 40 kb/s, which were utilized for analog/digital conversion, enabling the use of a Time Division Multiple (TDM) technique for signaling between the commander's station and the crew stations. The system utilizes the TDM technique in combination with the CVSD devices to reduce the cable requirements from an 18 conductor cable to a four-conductor cable and simplifies the modulation and signaling of the IR wireless subsystem which will be discussed later.

The TDM rate of the wireline system is 240 kb/s which is the result of the system developed in the study. The number of modes for the brassboard test system was reduced to modes, intercom only, and intercom plus radio from the intercom system developed in the study; however, the TDM rate was left the same. The final intercom, although more complex and providing more modes of operation, will work equally as well as the brassboard system.

The CVSD sampling rate of 40 kb/s was also a result of the trade-offs in the study portion of the contract. The 40 kb/s sampling provides approximately 4.5 kHz audio bandwidth or telephone quality audio link.

The system uses a "star" distribution technique in which the commander's station is the center distribution point. See Figure 2. The two modes of operation for the brassboard test system are intercom only and intercom plus radio. The infrared bit rate is 160 kb/s and operates, of course, at the same CVSD rate of 40 kb/s.

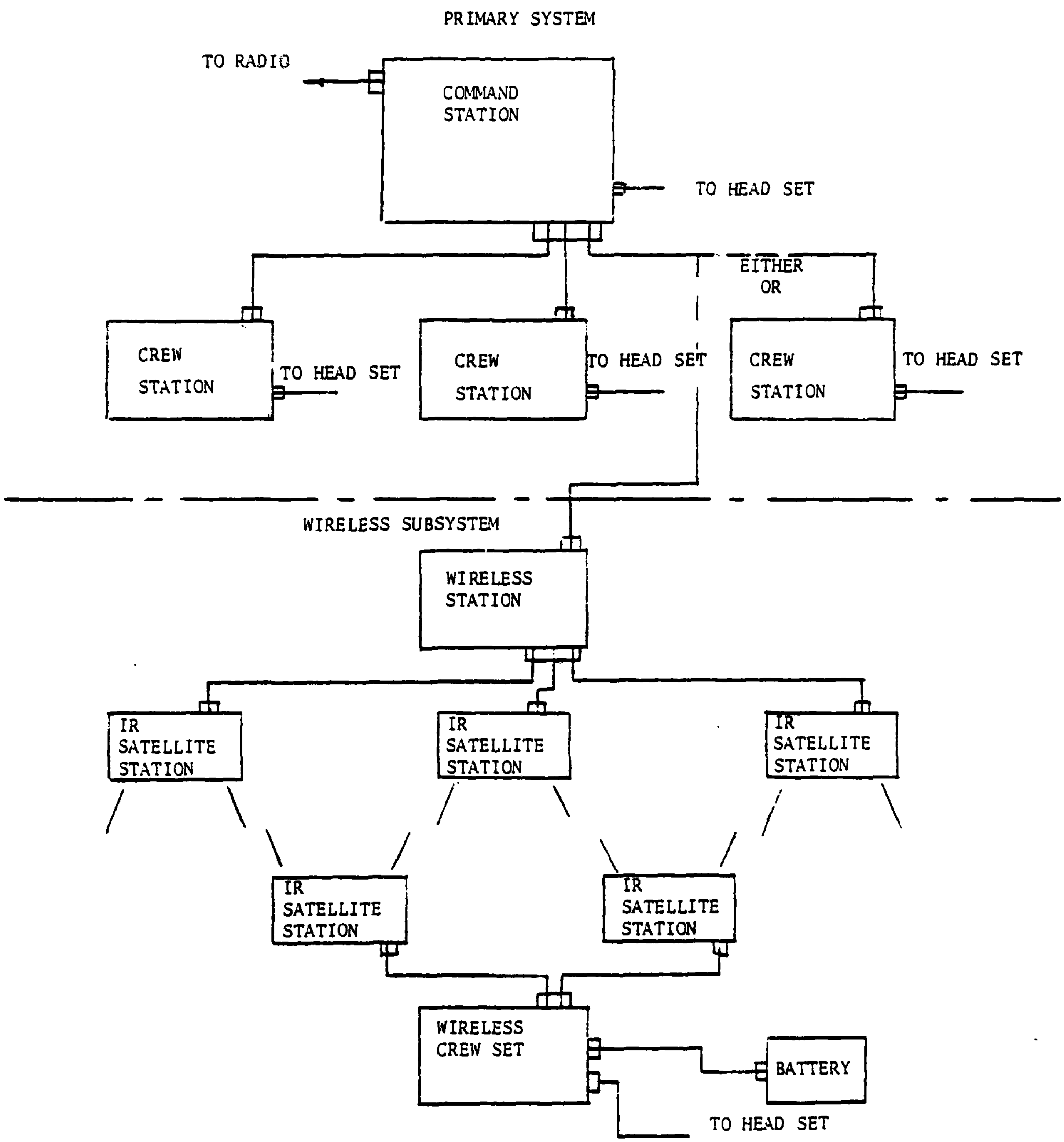

Figure 1. Block Diagram of Brassboard Test System

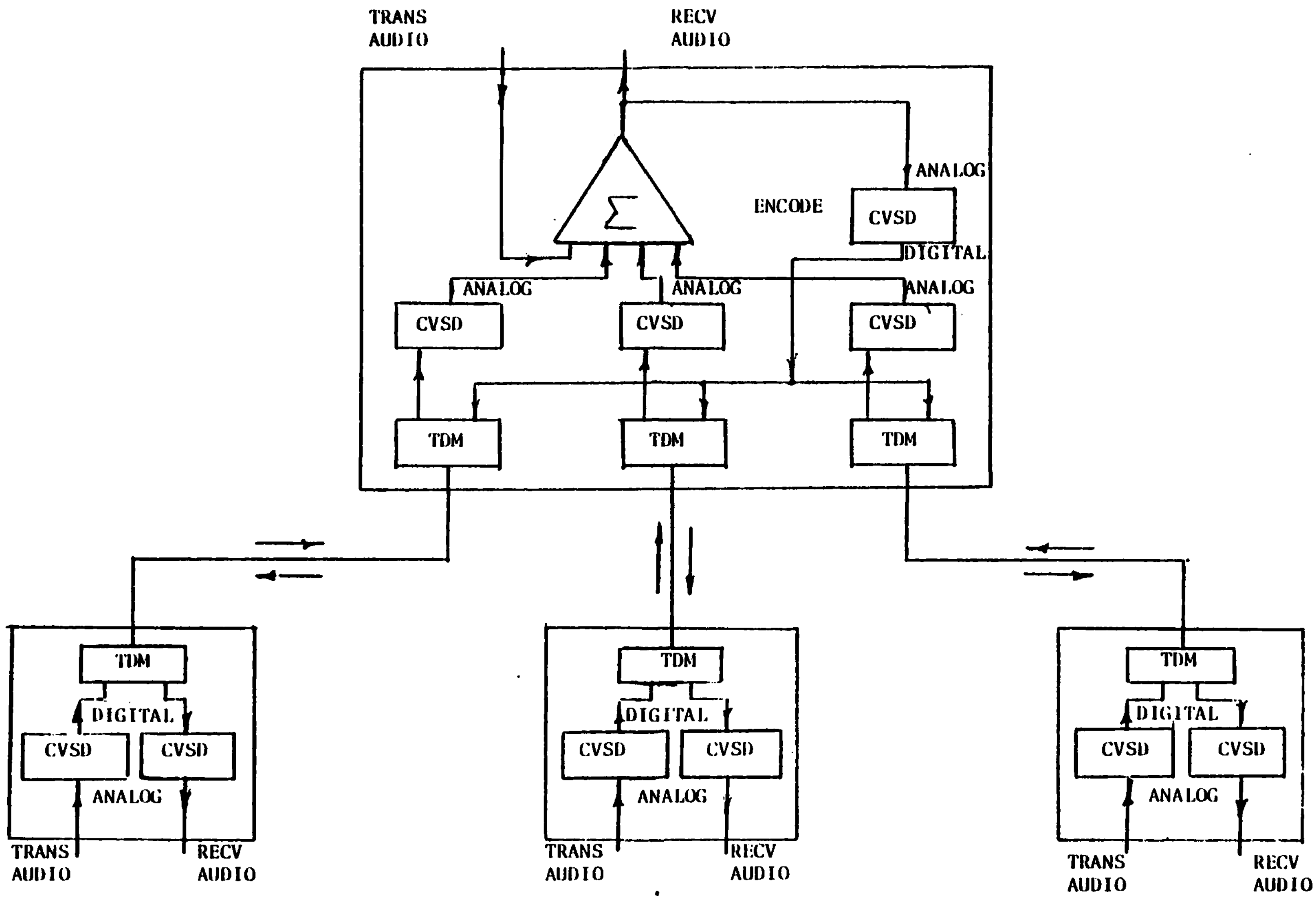

Figure 2. Simplified Audio Signal Flow Diagram

The communication link from one crew station to the commander's station is CVSD encoded and decoded one time. The communication link between one crew station and any other crew station is CVSD encoded and decoded twice.

The wireless subsystem is implemented into the intercom system by replacing a crew station with the wireless station. The interface to the commander's station is identical for both units, the crew station and the wireline station, see Figure 1. The wireless subsystem contains the wireless station which provides the interface between the infrared and wireline system. The wireless crew set provides the interface between the infrared and the crew member. The wireless station is linked to three IR transceivers. These transceivers were mounted to magnets, enabling mounting to any place in the M-60 tank and APC. The wireless crew set connects to two IR transceivers, one which was mounted in front and the second mounted on the back of the crew member operating in the wireless mode. The one-half intensity angle of the IR transceivers is 60 degrees, and the output is 15 mW per sterradian.

The audio section of the brassboard test system is the same as the audio circuitry recommended in the study portion of this contract. The block diagram of the audio section is shown in Figure 3. One of each type of equipment built for the brassboard testing is shown in Figure 4.

3. TEST AND TEST RESULTS

a. Test

Testing was conducted at Fort Knox, Kentucky the week of October 15, 1979.

The testing and test data is entirely qualitative in nature. This is due to the environment of and the nature of the tests. The brassboard intercom system was to be tested under the actual

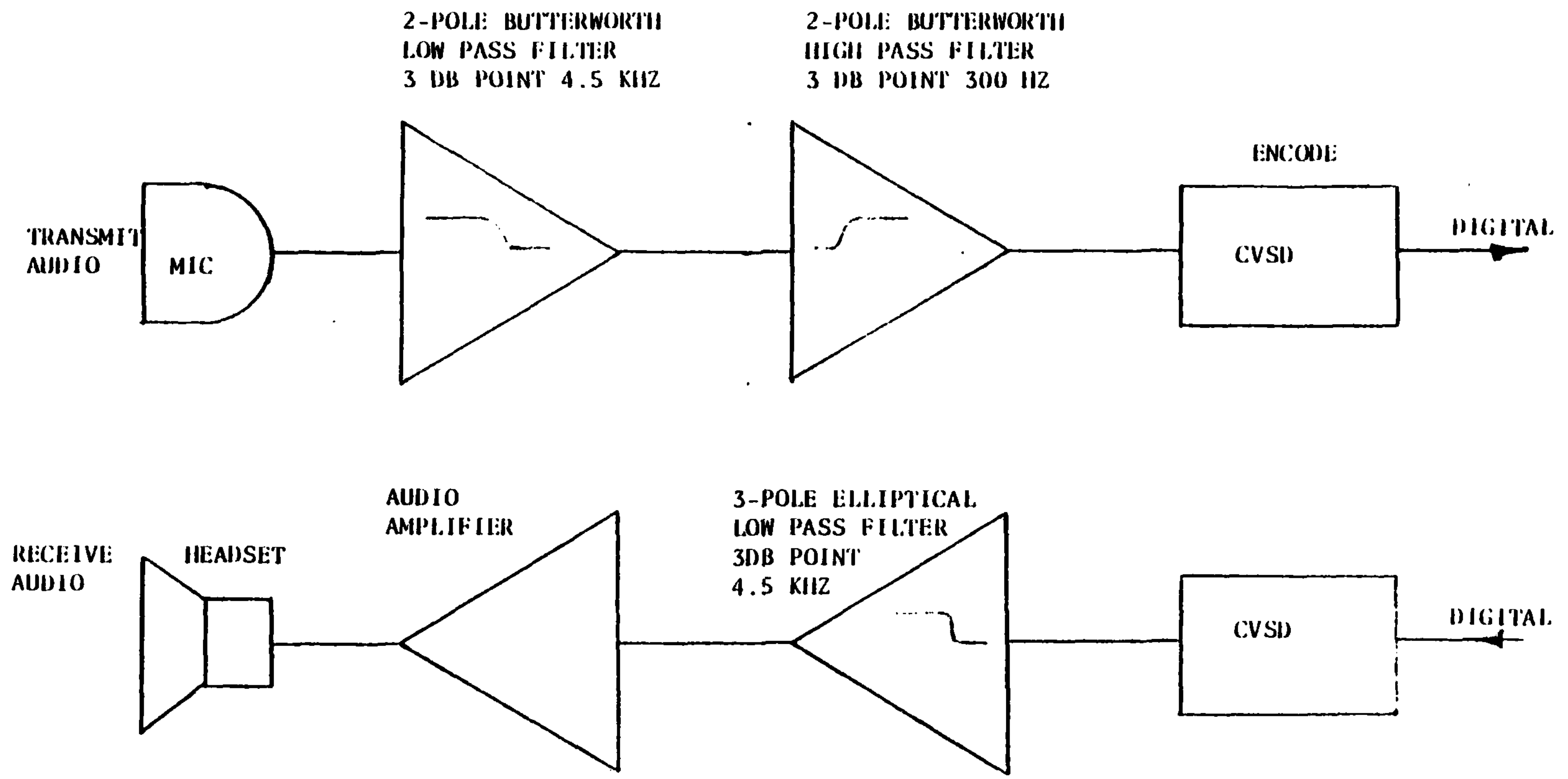

Figure 3. Audio Section Block Diagram

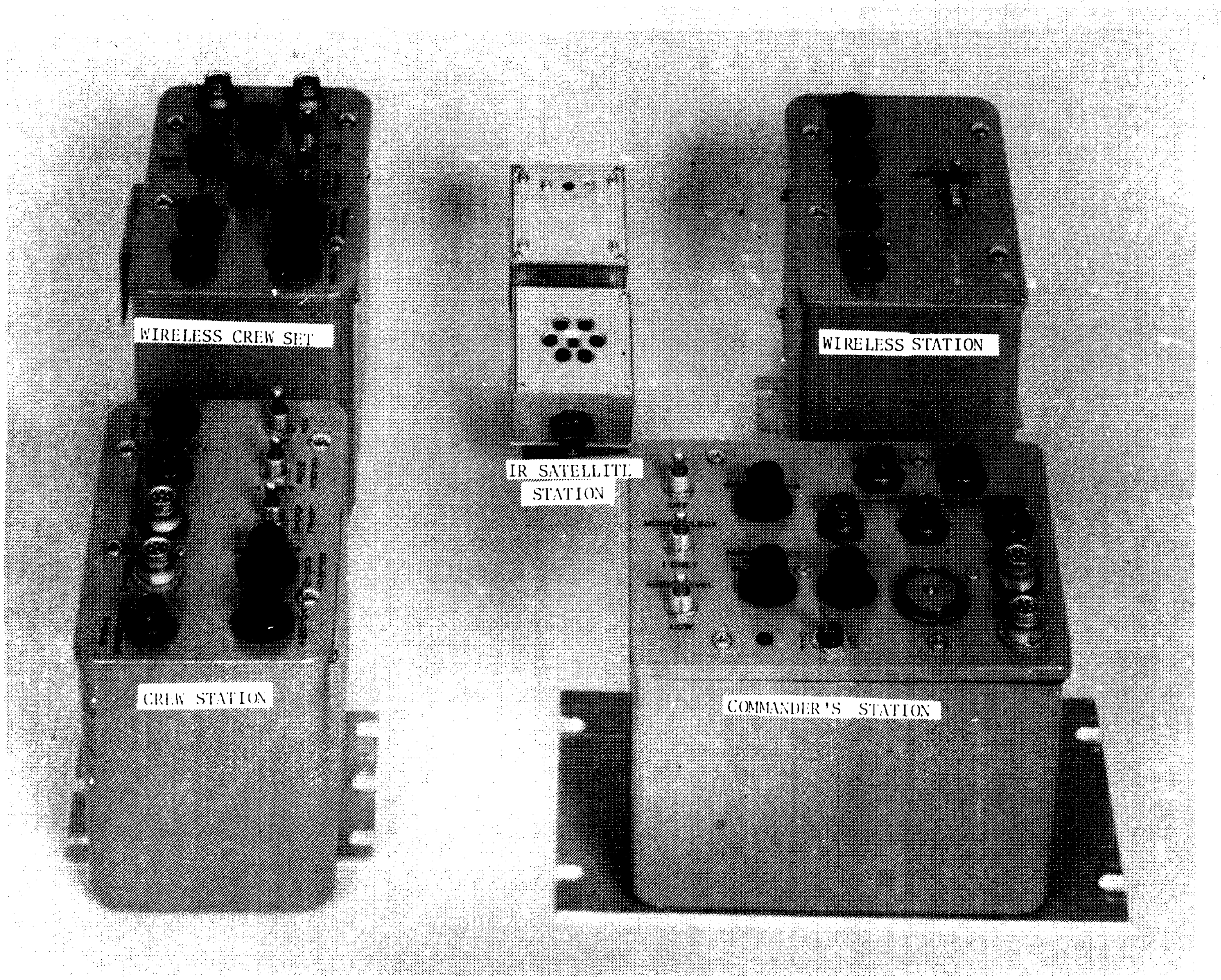

Figure 4. Brassboard Intercom Equipment

operating conditions of the tracked vehicles. This excluded the use of test equipment requiring 110 Vac. In the M-60, space was very limited and when in motion, the tracked vehicles would subject most commercial test equipment to shock and vibration levels higher than they were designed to withstand.

The object of the test was to determine performance of the brassboard equipment. This was done by comparing intelligibility of different test phases. The test in each vehicle will follow the pattern listed below:

- Intercom operated with vehicle not running
- Intercom operated with vehicle engine running but not moving
- Intercom operated with vehicle traveling at various speeds

To provide a means of analyzing the intercom operation, tape recordings were made during the testing in both the M-60 tank and the APC. The brassboard system was first tested in an M-60 tank.

Prior to installation of test system, the AN/VIC-1 intercom system was tested and recordings made of the intercom audio. The engine was started and operated at several engine speeds. The audio performance of the AN/VIC-1 had good intelligibility with some background noise. The most discernible noise was created by a generator blower motor. The tone was easy to hear at an idle speed (800 RPM) and grew harder to hear as the engine was increased in speed and could not be heard at 2,000 RPM.

b. Brassboard Testing in M-60 Tank

The brassboard system was then installed in the M-60. After the initial performance check the brassboard was tested with the vehicle not running.

The wireline primary system was tested with the communications links of interest being:

1. Commander to Loader (one CVSD conversion)

2. Commander to Driver (one CVSD conversion and through slip rings)

3. Driver to Loader (two CVSD conversions and through slip rings)

Each link was utilized a great deal and the audio quality in each link was very good. During the field testing, differences in audio quality between the three links could not be detected.

NOTE: When the system was tested on the bench, the two CVSD conversion links were slightly degraded from the one CVSD link.

With the engine not running, the audio quality was as good as a good audio telephone link.

One of the crew stations was replaced by the wireless station. The IR satellite stations were mounted to the turret to provide as close to a triangular pattern as possible. Due to the many obstructions in the turret, the transducer could not be placed in exactly ideal positions. The transceivers were also fairly close to the wireless crew member. This resulted in some nulls in the IR pattern. As the wireless crew member moved around in the turret area a loss in communications occurred when passing through these nulls. When the wire-

less crew member was not in one of the nulls, the audio quality was as good as the wireline links. The wireless subsystem was tested on a bright, sunny day. The sunlight had no effect on the wireless system when mounted in the tank turret with the hatches open.

Continuing the testing, the M-60 engine was started and the tests repeated. The blower motor noise heard clearly in the AN/VIC-1 system was barely discernible in the TDM system. The communications links were tested with no additional noise being added to the system except through the microphone. The driver (slip ring) link was given an additional test with the turret being traversed. This was not detected in the driver's communications link. The engine was operated at speeds between 800 RPM and 2000 RPM with no degradation to the brassboard intercom system.

The following on-board equipment was operated to determine if there was an interference problem either with the equipment interfering with the brassboard intercom or the intercom interfering with the on-board equipment.

- Gun Control Equipment
  - Stabilization Gyros
  - Automatic Fire Control Equipment
- Hydraulic Pump Motor

There was no degradation of performance of either the intercom system or the on-board tank equipment. The wireless system also was not degraded in these tests.

The next phase of the testing was with the M-60 moving. The AN/VIC-1 was replaced entirely by the intercom brassboard equipment. The driver and tank commander were able to use the brassboard equipment along with the personnel conducting the testing. This gave another parameter of the test. The drivers and tank commanders have utilized the AN/VIC-1 intercom. This gave a good comparison of the AN/VIC-1 to the new intercom brassboard system. The driver of the M-60 tanked stated that this was the quietest intercom he had used.

The wireline system and the wireless subsystem were both tested while the vehicle was moving. The wireless subsystem was tested first. The vibration and noise created by the moving vehicle did not cause the wireless intercom any problems. The performance was as good with the vehicle moving as it was in earlier tests with the vehicle not moving. During the wireless testing, the vehicle speed was limited to between five and 10 miles per hour.

The wireline system was then given a thorough test. The test vehicle operated both on a gravel parking lot and a sod area to provide different noise characteristics to the test system. The brassboard intercom operated equally well under both conditions. The vehicle was operated up to a speed of approximately 30 mph, and no additional noise was added to the intercom system via electrical paths. Noise was coupled into the intercom via the microphones when they were enabled. The equipment was given extensive testing through all of the communication links previously mentioned. No degradation was found in any of these links due to the vehicle moving.

c. Testing with Intercom in APC

Installation in the APC was completed without difficulty and static tests were run on the primary wireline system and the wireless subsystem.

Locating the IR transceivers in the APC was easier than in the M-60. The transceivers could be mounted farther from the wireless crew member allowing for wider dispersion of the infrared energy. Nulls were still present in the IR pattern but they were narrow and caused only momentary losses in communications.

The wireline system was tested through the commander to crew station (one CVSD conversion) and crew station to crew station (two CVSD conversions). There are no slip rings in the APC and therefore only the above two communications links were tested. The brassboard intercom system worked as well in the APC as in the M-60.

The wireless and wireline systems were then tested in the APC while it was moving. The ambient noise is much higher in the APC at high speeds than in the M-60 tank. The background noise remained at a low level when the headsets were not keyed. When enabled the microphones added noise to the system, but even with the added noise commands could be plainly heard over the brassboard intercom system. Received radio messages did not have the added background noise and were very clear. The brassboard system operated as well in the APC as in the M-60 tank.

d. Accessory Testing

Bone Conduction Microphone

A bone conduction microphone was tested as a possible solution to the ambient noise problem. The microphone proved to be very sensitive to vibration, and added noise through the system via vibrations through the user's body. The frequency response of the microphone was low and voice reproduction was not good.

VOX

The VOX selected in the study for use in noise environments used a variable threshold technique. This system performed well with constant noise levels. The noise in tracked vehicles is not constant but consists of many noise impulses. The noise impulses caused the VOX circuit to key the intercom system. In instances of high background noise the VOX circuit constantly keyed the intercom system. There was no opportunity to develop the VOX circuit to match the special noise environment in which it must work. The VOX circuit in its present form would not be acceptable for use in tracked vehicles.

This circuit could be optimized to the tracked vehicle background noise however it is doubtful that all false keying due to noise could be eliminated.

CORADCOM Microphone

A microphone which was the result of a program conducted by CORADCOM was tested with the brassboard intercom system. This microphone performed significantly better than the present standard issue microphonesbut wind noise is still very prevalent at high speeds. Many comparisons were made between the two microphones with the new microphone consistently out-performing the old. Tape recordings were made of both microphones in various noise environments for later analysis.

Dc Characteristics of Tracked Vehicles

The dc battery which supplies the power to the intercom was of interest. These lines, if not isolated, can contribute to the noise of the intercom system. These lines were monitored with an oscilloscope and pictures taken of the noise with the vehicle operating at idle and full engine speed. These pictures are shown in Figure 5. Also checked at this time was the amount of noise injected onto the battery lines by the intercom system. These pictures are shown in Figure 6.

4. CONCLUSION

a. TDM Utilizing CVSD Devices

The audio quality of the brassboard intercom system was very good. The system performed as well as a telephone link, which provides voice and stress recognition. The TDM technique provided noise immunity better than the AN/VIC-1 for signal routing between commander and crew stations and requires only a four-conductor cable between stations. The CVSD devices operating at 40 kb/s rate provided a low distortion A to D, D to A conversion with no synchronization problems and limited amount of hardware. The slip rings of the M-60 did not degrade the TDM system which was operating at a 240 kb/s rate. TDM signaling will perform well in track vehicles, provide the noise immunity gained by digital signaling, and reduce the cabling requirements of the intercom system.

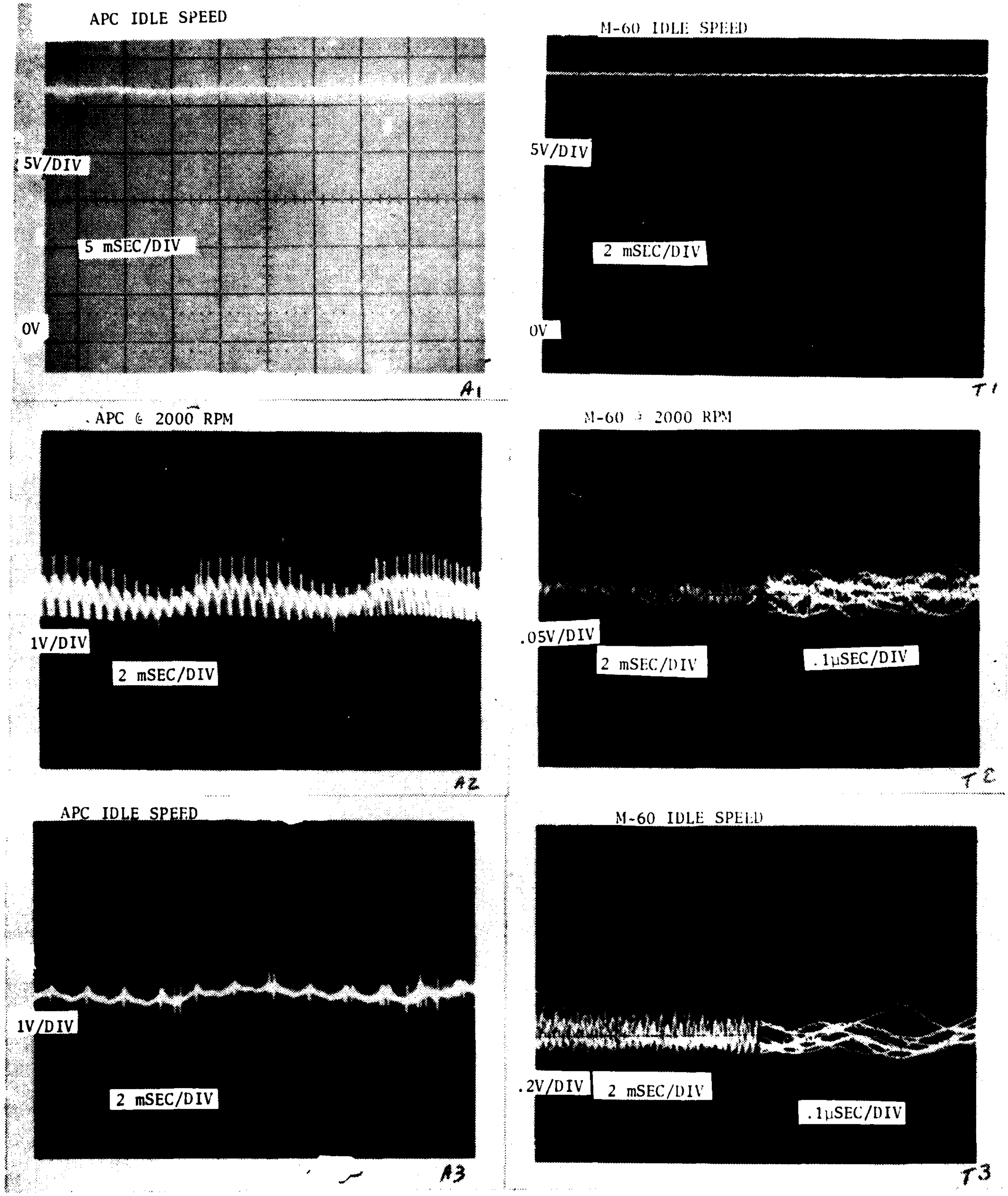

Figure 5. DC Lines of Tracked Vehicles with Intercom OFF

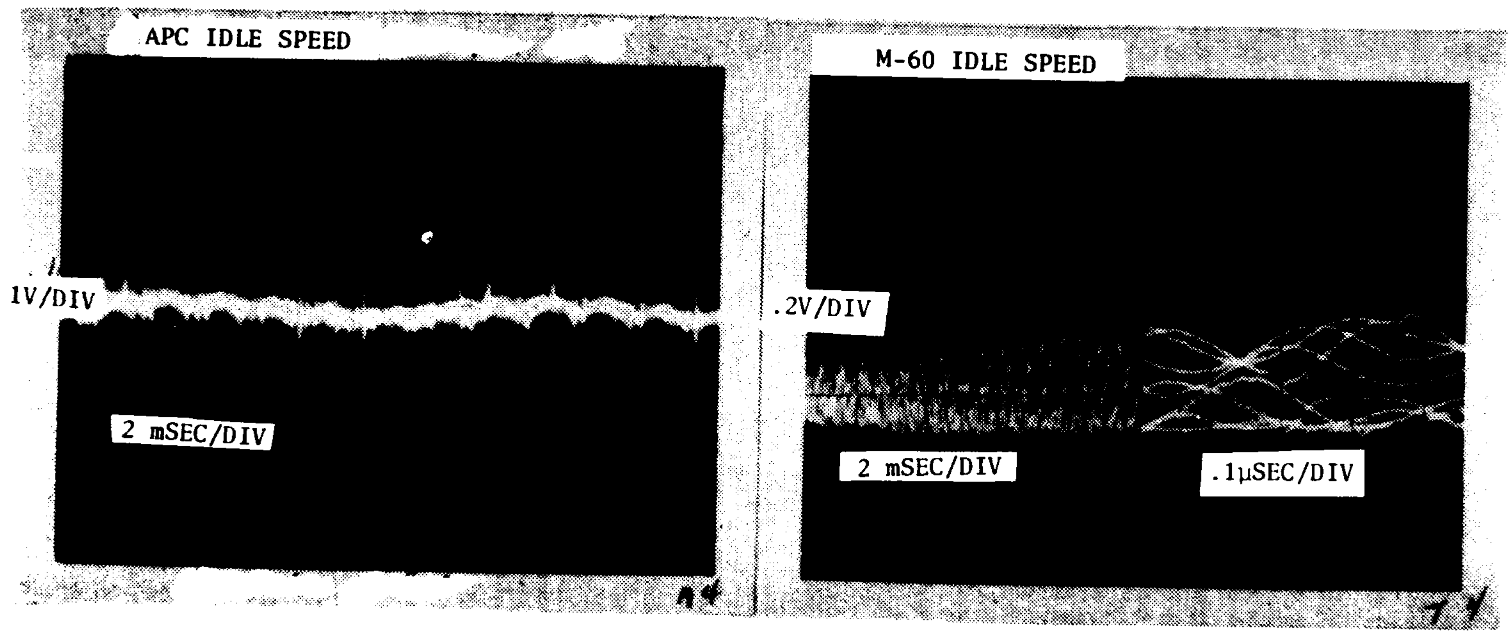

Figure 6. Vehicle DC with Brassboard Intercom ON

No COMSEC equipment was used in the tests. From the quality of recovered digitized voice, it is unlikely that 40 kb/s CVSD will degrade 16 kb/s encoding and decoding associated with COMSEC operation.

b. IR Wireless

The IR wireless system performed well for an initial test of a fairly new concept. The problem of nulls in the turret and APC area can be solved by increasing the number of satellite transceivers and widening the one-half intensity angle of the emitters.

Infrared devices for signaling and communications are fairly new. There is a high degree of interest in the infrared area and it is anticipated that better and more inexpensive devices will be available in the future.

Sensitivity of the IR system was lower than that prediced by the analytical analysis performed in the study phase. Therefore, large improvements can be expected in the IR system which would make it more feasible than a brassboard system tested. Problems to resolve, however, are IR transceiver location on the IR operator, the logistics of the crew set electronics, batteries for the wireless crew set, and the IR transceivers. These items will be relatively small in size and may be difficult to keep in inventory.

c. Accessories

Bone Conduction Microphone

The bone conduction microphone had a fairly low frequency response and tended to add distortion to the audio. The microphone was also very sensitive to vibration and would require more development work before it could be applied to a tracked vehicle application.

d. VOX Circuit

The VOX circuit did not perform up to its expectations due to the large amount of impulse noise present in a tracked vehicle environment. However, if a limited number of falsings are considered acceptable, a VOX is still feasible to provide hands-free keying.

e. CORADCOM Noise-Canceling Microphone

The noise-canceling capability of the new microphone was better than that of the existing microphones. This microphone, or one with similar or better performance should be considered for the new intercom system.

f. Impact of Testing on Study Baseline System

The major techniques (TDM, and IR wireless used in intercom brassboard system performed up to all expectations. The TDM signaling system with CVSD coding provided a high quality very reliable intercom system.

The infrared radiation for the wireless intercom system demonstrated feasibility. This technique would require development work before it could be implemented into a wireless intercom system. There is presently a lot of activity in developing infrared wireless systems in the commercial area such as wireless stereo headphones and wireless telephones. This activity will aid in the development and improvement of an infrared wireless sytem capable of operation in tracked vehicles.

The testing of the brassboard system has confirmed that the baseline system defined in ITT-A/OD in the final report of this program is a very viable approach for future intercom systems. This system would be a wireline system with the capability of adding a wireless subsystem, without modification when wireless operation is required.

The brassboard tests have provided a high confidence level that the ITT-A/OD baseline system is the intercom for future tracked vehicles.

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